ALGORITHM/DATA PROCESSING TECHNICAL REPORT
FOR THE
VISIBLE/INFRARED IMAGER RADIOMETER SUITE (VIIRS)

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CHANGE RECORD PAGE

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1 SCOPE

1.1 Identification

This Algorithm/data Processing Technical Report applies to Visible/Infrared Imager/Radiometer Suite (VIIRS) Phase II task.

1.2 System Overview

The purpose of the VIIRS Phase II system is to support development, test, and optimization of the VIIRS algorithms in pre-operational versions that will be suitable to be used with the VIIRS sensors. Sub-System development will reuse major components of the MODIS production system and other suitable model components, compatible with VIIRS processing concepts and will implement the features required for VIIRS data processing, production and archiving.

1.3 Document Overview

This document describes the Algorithm Theoretical Basis Document (ATBD) development plans for Phase II. The ATBDs had reached a PDR level of maturity at the end of Phase I. Since the start of Phase II Raytheon has completed its own internal review of the ATBDs. In addition the IPO has issued an algorithm Watch List which highlights specific areas of the algorithm development that need additional visibility in Phase II. Finally, comments on the ATBDs have been received from individual members of the VIIRS Operational Algorithm Team (VOAT). Each of these sets of comments form the basis for the work plan to be completed in Phase II.

There will be two new versions of the ATBDs. Version 4 will be delivered in MAY01 and contain updates based on comments described above and will also contain reference to additional changes that will be implemented in version 5.

Version 5 will be delivered in FEB02 at the System CDR and represents the final version of the ATBDs under the present SBRS VIIRS contract.

In addition to this document Raytheon has released two other relevant documents relating to software development. These are:

- VIIRS Algorithm Software Development Plan, Y6635
- VIIRS Algorithm Software Maturity Assessment, Y6661

The VIIRS Algorithm Software Development Plan (SDP) describes the Raytheon ITSS Team's approach to software development for the VIIRS algorithm subsystem and includes the specific methods and procedures (technical and managerial) of the responsible organizations, which are to be employed during the course of the project. The processes described therein reflect the requirements of the Software Engineering Institute's (SEI's) Capability Maturity Model (CMM), Version 1.1, and the SEI's Method for Assessing the Software Engineering Capability of Contractors (1987) at Level 2 and applicable Key Process Areas at Level 3. The VIIRS Team believes in rigorous, repeatable processes that promote efficiency, lower cost, and reduce risk. SEI compliance encourages the achievement of these goals and gives the project the best possible chance of success. As a result, Raytheon management, DoD, NOAA and NASA are afforded visibility into project progress. The ITSS SDP Template from which this SDP was prepared is installed on the ITSS Quality Assurance (QA) Server for downloading, as required.

The VIIRS Algorithm Software Maturity Assessment describes the degree to which the VIIRS Data Processing Architecture has been implemented and lists areas where modifications are due and provides insight as to the type of modification required.

The present document is organized into 4 sections. The contents of these sections are as follows:

- **Section 1, Scope** - This section provides an introduction to the document, including the identification of the system, a system overview, an overview of the contents of the document.
- **Section 2, Referenced Documents** - This section provides a list of all documents referenced.
- **Section 3, Algorithm Watch List Development Plan** - This section includes each of the 13 Algorithm Watch List items: a statement of the item followed by the Raytheon plan to overcome the concern expressed. These items are listed separately in order to maintain their visibility. As of 22MAR01, five of these items have been retired.
- **Section 4, ATBD Development Plans** - This section describes the specific tasks that will be addressed as part of the ATBD development in Phase II. It is derived from Raytheon's internal assessment of the maturity of each ATBD and on the comments received from the IPO VOAT, which can be found in Appendix A.

Appendix A is the original set of IPO VOAT comments received in the March 2001 timeframe.

2 REFERENCED DOCUMENTS

This section provides a listing of all documents referenced in this document.

2.1 Non-Government Documents

The following documents of the exact issue shown form a part of this report to the extent specified herein.

- VIIRS Algorithm Validation and Verification Plan, Y3270
- VIIRS Algorithm Software Development Plan, Y6635
- System Verification and Validation Plan, SBRS Document #: TP154640-001
- All VIIRS ATBDs
- VIIRS Algorithm TIM1. Held at Lanham, MD, 11JAN01

3 ALGORITHM WATCH LIST DEVELOPMENT PLAN

This section includes each of the 13 Algorithm Watch List items. A statement of each item is followed by the Raytheon plan to overcome the concern expressed. These items are listed separately from the ATBD development plan in order to maintain their visibility. Table 1 traces the Watch List Items, the IPO Point of Contact and the ATBD affected by them.

Table 1. VIIRS Algorithm Watch List items, POCs, ATBDs affected, and current status (30MAR01).

Watch List Item	POC(s)	ATBD(s) Affected	Status
SST Algorithm Performance	May, Legeckis, Minnett	SST	Open
3D Effects for Aerosols	Shettle, Lyapustin, Heidinger	Aerosols, Surface Reflectance	Open
Forward Modeling	Shettle, Lyapustin	Numerous ATBDs	Open
Mean Particle Size	Heidinger, Shettle, Kopp	Cloud Optical Properties	Closed
Surface Directional Effects	Privette, Hall, Tarpley, Lyapustin	VI, Albedo, Snow Cover, LST	Closed
Albedo Neural Network	Privette	Albedo	Closed
Snow Cover	Tarpley, Lyapustin, Kopp, Privette	Snow Cover	Closed
Impact of Cloud Mask	Kopp, Heidinger, Menzel	Cloud Mask, most others	Open
Clouds and 3.9 microns	Kopp, Menzel	Cloud Mask, Cloud EDRs	Open
Striping and Stability	Weinreb, Guenther	RDR to SDR Conversion	Open
Polarization Correction	Esaias, Brown	Ocean Color, Remote Sensing Reflectance	Open
Fire Algorithm	Murphy, Prins, Kaufman	Active Fires	Open
NCC Algorithm Product	Kopp	Imagery	Closed
Other Sensor Issues	See sensor POCs	Most ATBDs	Open

3.1 SST Algorithm Performance

Watch List Concern

SST algorithm performance needs rigorous attention & iteration w/ sensor team.

Raytheon Response

Sea Surface Temperature (SST) is a NPOESS key EDR and VIIRS Category IA EDR. Two fundamental Phase II activities are the rigorous attention to the SST algorithm performance and the iteration between the algorithm and sensor teams.

Raytheon will rigorously monitor the SST algorithm performance as it is modified by the algorithm and sensor design refinements in Phase II. Raytheon will undertake coordination with the MODIS research/operational algorithm committees during this phase. Lastly, Raytheon will monitor the SST performance by a Technical Performance Metric (TPM) that will be tracked at the system level. Algorithm coordination meeting with VOAT POCs being planned for APR01.

3.2 3D Effects for Aerosols

Watch List Concern

Incorporation of 3D effects for aerosols over land may avoid large systematic errors.

Raytheon Response

Currently, handling of 3D effects in the radiative transfer models and retrieval algorithms is under development by the community. Raytheon will monitor the progress of Y. Kaufman and A. Lyapustin with regard to algorithmic solutions and analyses for MODIS. If a viable solution is achieved by MODIS, Raytheon will evaluate the cost and benefit of implementation. A. Lyapustin invited for seminar at Raytheon on 6APR01.

Raytheon’s lookup table generation tool will be sufficiently generic and flexible in order to incorporate advancements in RT modeling.

3.3 Atmospheric Forward Modeling

Watch List Concern

Current atmospheric forward modeling (especially for aerosol and ocean color applications) may have inadequate treatment of path radiance and gaseous absorption.

Raytheon Response

The user community desires a more thorough evaluation of 6S relative to MODTRAN and other models. There are concerns regarding the treatment of gaseous absorption in the 6S model. This activity requires resources that are beyond the scope of Phase II. Raytheon will monitor and participate in a community-based evaluation of 6S relative to other models. Raytheon will switch the baseline model for the Net Heat Flux lookup tables to MODTRAN.

Raytheon's lookup table generation tool will be sufficiently generic and flexible enough to implement whichever model proves best for each EDR.

3.4 Estimation of Mean Particle Size (Cancelled on 22MAR01)

Watch List Concern

Process for estimation of mean particle size from cloud top value may degrade CPS.

(There is an inadequate discussion of the assumptions about vertical distribution necessary to translate the measured cloud top value to a layer mean value. Techniques exist to perform this correction based on recent well-known results.)

Raytheon Response

Raytheon will deliver the cloud top value and clarify this in the ATBD, allowing end user to extend the output to layer mean via the appropriate technique.

3.5 Surface Directional Effects (Cancelled on 22MAR01)

Watch List Concern

Consideration of surface directional effects will better address EDRs (Albedo, VI, Snow Cover) based on solar reflective bands. There is insufficient use of BRDF-modeled surfaces in Phase I analyses for land EDRs, angle-dependent surface reflectance/VI products and insufficient documentation of intermediate products

Raytheon Response

Raytheon has incorporated directional effects into the error budget.
Raytheon will coordinate with the VOAT to monitor the advancements on this topic. Analogous solutions where operationally viable, particularly for albedo, snow cover and VI will be implemented.

Surface albedo algorithm baseline has been switched to a MODIS-like approach for dark surfaces. As VI is already a suite of products, Raytheon will consider the addition of an angle-independent product (probably as part of generating the Monthly Vegetation Index) that should be adaptable for a low cost from MODIS. BRDF-correction solution being developed for V4 of Snow Cover ATBD.

3.6 Albedo Neural Network (Cancelled on 22MAR01)

Watch List Concern

Albedo neural network approach (for rare events). The largest issues are maintaining the training database, concerns about binning and how BRDF is handled, concerns about retraining implications and fallback algorithm not sufficiently developed or described.

Raytheon Response

Central trade issue in Phase I was higher risk and better performance versus lower risk and poorer performance. Converting the angles into inputs instead of binning by angle could alleviate training issues. Raytheon agrees that any approach must be verified against anisotropic surface models.
Based on new MODIS validation results, Raytheon is switching the baseline algorithm for dark surfaces to a MODIS-like approach. The neural network is being retained for bright surfaces (snow and desert).

3.7 Snow Cover (Cancelled on 22MAR01)

Watch List Concern

Snow Cover EDR performance at large solar zenith angles and for various cloud cover and surface conditions. Possible disadvantage is dependence on absolute reflectance. Atmospheric correction errors should be studied in detail and BRDF effects. MODIS derived non-snow spectra will be very limited by discrete MODIS sun-view geometries.

Raytheon Response

Raytheon concurs that the solar zenith angle over snow will often exceed current solar zenith angle limits of 70 degrees on specification performance for the Snow Cover EDR. Phase I solutions stipulated that beyond limits, the EDR would be reported but not guaranteed to meet the specification, as indicated in the Algorithm Subsystem Specification. This will be clarified in versions four and five of the Snow Cover/Depth ATBD, as well as for all other ATBDs where the issue currently is not clarified. The development of the monthly non-snow reflectance IP will begin in Phase II as part of the LUT generation tool. BRDF modeling will be implemented to handle the limited sun-view geometries.

3.8 Impact of Cloud Mask

Watch List Concern

Impact of Cloud Mask (clear, cloudy, aerosol distinction) for EDR production and performance

Raytheon Response

Raytheon agrees that the interplay between the Cloud mask and the rest of the VIIRS system is a central issue leading into CDR. Within the scope of Phase II, Raytheon will further refine the definitions of “probably cloudy” and “probably clear”.

Raytheon will continue to explore the impacts of these definitions on EDR coverage and performance. The intermediate products will be more fully described in the Earth Gridding ATBD. Raytheon is closely working with MODIS Cloud Mask team to maximize leverage of current technology.

3.9 Cloud Algorithm Dependence on 3.9 um

Watch List Concern

Cloud algorithm is critically dependent upon sensor performance in 3.9 m region

Raytheon Response

Tools are already in place to investigate the utility of the 4.05 and 3.70 um bands as fallbacks for the 3.74 um band in the cloud mask algorithm. These tools are within the scope of the cloud mask tuning in Phase II. Raytheon will consider the implementation of additional tests that are documented, coded, and operationally accepted. Performance of Cloud EDRs at low temperature will continue to be monitored as part of normal work.

3.10 Impact of Striping/Calibration Stability

Watch List Concern

Impact of striping, calibration stability on EDR performance

Raytheon Response

Raytheon recognizes the importance of these two topics and the level of effort being expended to address striping for MODIS. Continued verification of EDR performance as affected by the evolution of the sensor design and EDU fabrication is a nominal Phase II task. Particular attention will be given to a number of issues, including but not limited to the striping and calibration stability. Raytheon will closely monitor the results obtained by the MODIS team regarding the algorithmic solutions to striping. The MODIS heritage should provide a basis for the VIIRS algorithmic solution.

3.11 Polarization Correction for Ocean Color

Watch List Concern

Polarization correction algorithm for ocean color

Raytheon Response

The tightened polarization specifications are achieved with margin. The changes provide 8-83% margin across +_ 45-degree scan range. Excellent characteristics are achieved across the entire +-56 degree scan. Amplitude knowledge of 0.5% and phase angle knowledge of 5 degrees.

A dual mirror de-polarizer was added at the end of Phase I to improve the polarization performance. This allowed tightening of the polarization specification to 3% or less across all bands related to ocean color retrievals. In most cases, there is significant margin against this specification (predicted performance of 2% or less) that reduces the reliance on the algorithmic solution. E. Vermote is continuing development and documentation of the correction algorithm. Close collaboration with the MODIS ocean group is also foreseen.

This issue will be monitored as a normal part of Phase II activities as a Technical Performance Metric (TPM).

3.12 Development of Fire Algorithm

Watch List Concern

Development of fire algorithm

Raytheon Response

Due to its late arrival in to the SRD and its category IIB status, Raytheon has provided essentially an SRR-level solution for this product at PDR. Raytheon agrees that further development is necessary to bring this product to an appropriate level of maturity at CDR. Close monitoring of MODIS and Raytheon Hazard Support System analyses and results will help to ensure a strong CDR solution. One algorithm coordination meeting already held for Active Fires.

3.13 NCC Algorithm Products (Cancelled on 22MAR01)

Watch List Concern

“Seams” will be present in the NCC product, rather than a smooth image.

Raytheon Response

The OLS heritage approach will be implemented at launch. The OLS processing is onboard and Raytheon will request this algorithm and OLS test imagery for Phase II development. Modifications to suit the VIIRS DNB will be tested on simulated imagery, using OLS scenes and DNB sensor models.

If the algorithm developed in Phase I becomes necessary and is sufficiently mature, then it will be phased into post-launch.

3.14 Other Sensor Issues

Watch List Concern

Other sensor issues (Stray light, detector operability, FPA technology) as they impact EDR performance

Raytheon Response

Tracking of such issues is considered part of normal work.

4 ALGORITHM THEORETICAL BASIS DOCUMENTS DEVELOPMENT PLANS

This section describes the specific tasks that will be addressed as part of the ATBD development in Phase II. It is derived from Raytheon's internal assessment of the maturity of each ATBD and on the comments received from the IPO VOAT. This section is organized by ATBD and not by EDR. Some ATBDs cover more than one EDR. In addition, some ATBDs have been written to address intermediate products and are not in response to explicit EDR requirements. Table 2 summarizes the ATBDs.

For each of the ATBD plans thereafter, Phase II tasks are grouped into three categories: watch list related tasks (if any), internally identified tasks regarding specific ATBD sections, and a tally of relevant IPO/VOAT comments from Appendix A. These comments are in turn grouped into three categories: implement (make the suggested change in the ATBD), advice (consider the suggested change in the ATBD), and comment (IPO/VOAT comment only; no corresponding change in ATBD or algorithm expected).

Table 2. VIIRS Algorithm Theoretical Basis summary.

NPOESS/VIIRS ALGORITHM THEORETICAL BASIS			
ATBD	**Baseline Approach**	**Heritage**	**ATBD#**
Imagery	Tie points for sea ice, Gain	Adapted	Y2466
Sea Surface Temperature	4-Channel Regression w/ Air Mass, Cirrus, Aerosol Correction	Adapted	Y2386
Soil Moisture	CMIS/VIIRS Data Fusion	Adapted	Y2387
Aerosol Opt. Thick. & Part. Size	Dark Pixel Method	Adapted	Y2388
Suspended Matter	Multiple Indices & Dominant Type	Adapted	Y2390
Cloud Base Height	Cloud Propery LUT	Adapted	Y2391
Cloud Cover/Layers	Statistical/Cloud Properties	Adopted	Y2392
Cloud Optical Properties	UCLA Ice & Water RT Modeling	Adopted	Y2393
Cloud Top Parameters	UCLA Ice & Water Infrared RT Modeling	Adopted	Y2395
Surface Albedo	Combination of Kernel-driven and Neural Net	Adapted	Y2398
Land Surface Temperature	4-Channel Regression w/ Emissivity Correction	Adapted	Y2399
Vegetation Index	NDVI, EVI, Secondary Products (e.g., LAI)	Adopted	Y2400
Snow Cover	Binary NDSI Mapping, Spectral Unmixing	Adopted	Y2401
Surface Type	Decision Tree	Adapted	Y2402
Ocean Current	Maximum Cross Correlation	Adopted	Y2403
Fresh Water Ice	Energy Budget/Spectral Unmixing	Adopted	Y2404
Ice Surface Temperature	Split Window Regression	Adopted	Y2405
Littoral Sediment Transport	Bathymetry	Developed	Y2406
Net Heat Flux	Regression/Neural Net/Bulk	Adapted	Y2407
Ocean Color/Chlorophyll	MODIS Case 2 Regionally Tunable	Adapted	Y2408
Remote Sensing Reflectance (IP)	Improved SeaWiFS w/ Full Residual Polarization Handling	Adapted	Y2389
Sea Ice Age/Edge Motion	Maximum Cross Correlation	Adapted	Y2409
Mass Loading	Physical Retrieval	Adapted	Y2410
Surface Reflectance (IP)	Radiative Transfer LUT	Adopted	Y2411
Cloud Mask (IP)	Dynamic Thresholding, Spatial Variability	Adapted	Y2412
Precipitable Water	5-Channel Regression	Adapted	Y3251
Active Fires	Contextual Analysis	Adopted	Y3252
RDR to SDR Conversion	Calibration, MODIS Destriping	Adapted	Y3261
Geolocation	Calibration to Ground Control Points, Line-of-Sight Coordinate Transformations, Terrain Correction	Adopted	Y3258
Earth Gridding	Mapping Anc/Aux Data, etc. to Common Grid	Adapted	Y7051

ATBD: Imagery

ATBD#: Y2466

- Watch List Item 13 (NCC Algorithm Products, cancelled 22MAR01)
    - Acquire OLS imagery for test data from AFWA.
    - Acquire access to the OLS terminator imagery processing code. Formal request, through appropriate channels.

- Section 3.0
    - Sections 3.3.5, 3.3.6, and 3.3.7 (NCC Imagery) – Responsive to watch list item 13. No revision needed for version 4. Version 5 will need development of the OLS based algorithm as suggested above to respond to item 13.
    - Section 3.5.3 of ATBD (Theoretical Description: Sea Ice) – For version 4, should add a subsection on Search Windows, giving an overview of their efficacy for this EDR. For version 5, should expand to include optimization studies (with MODIS validation data, if possible).
    - Section 3.5.5 of ATBD (Practical Considerations: Sea Ice) – Needs expansion for version 5.
    - Section 3.5.6 of ATBD (Initialization and Validation: Sea Ice) – Use of MODIS validation data.
    - Define flags
    - Develop “user manual” for manual cloud analysis
    - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 4 Implement
    - 0 Advice
    - 0 Comments

ATBD: Sea Surface Temperature

ATBD#: Y2386

- Watch List item 1 (SST needs rigorous attention and iteration with the sensor team)
    - Part of normal work, tracked via TPM

- ATBD Sections/Issues
    - Cirrus detection/rejection
    - Optically thin cirrus detection/rejection/correction (daytime/nighttime)
    - Aerosol correction during daytime/nighttime
    - Skin/radiosonde adjustment for training
    - Incorporation/refinement of ocean emissivity model when mature and available from IPO community
    - Ocean surface solar reflection incorporation
    - Finalization of aerosol models for correction
    - Fine/moderate EDR ground pixel compositing scheme
    - Improve readability of ATBD
    - Add quality flag functionality
    - Delete flowdown information
    - Implement many relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 77 Implement
    - 15 Advice
    - 35 Comment

ATBD: Soil Moisture

ATBD#: Y2387

- No Watch List items related to this ATBD

- ATBD Updates
  - Develop approach for segmenting VIIRS swath into granules that can be processed by this algorithm (must be big enough to include sufficient CMIS samples, but small enough not to be swamped by natural variability across the region of interest
  - Test above-mentioned approach, using a combination of TRMM/VIRS, TRMM/TMI, and gridded AVHRR products.
  - Refine error budget with regard to the various inputs for this EDR
  - Set up a process for monitoring the progress of CMIS development
  - Develop and refine quality flags, and also the strategy for falling back to a microwave-resolution product where cloud cover exists
  - Define flags

- No IPO/VOAT comments received for this ATBD

ATBD: Aerosol Optical Thickness and Particle Size Parameter

ATBD#: Y2388

- Watch List items 2 (3-d effects for aerosols) and 3 (Atmospheric forward modeling)
    - Monitor results of Lyapustin and Kaufman, invite both for seminars to determine viability for VIIRS

- ATBD Updates
    - Consideration of aerosol height
    - General consideration of additional aerosol models to test extreme (but not necessarily rare) cases, such as more emphasis on windblown dust
    - Refine relationship between these two EDRs and the Suspended Matter EDR
    - Define output flags and their format
    - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 5 Implement
    - 6 Advice
    - 11 Comment

ATBD: Suspended Matter

ATBD#: Y2390

- No Watch List items related to this ATBD

- ATBD Updates
  - Refine relationship between this EDR and the Aerosol EDRs
  - Refine relationship between output classes and the needs of downstream EDRs such as SST
  - Specify required validation data
  - Define output flags and their format
  - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
  - 2 Implement
  - 1 Advice
  - 5 Comment

ATBD: Cloud Base Height

ATBD#: Y2391

- No Watch List items related to this ATBD

- ATBD Modifications:
  - Define output flags and their format
  - Incorporate material from 5.0 "Conclusions" section into 1.0 "Introduction" and/or 4.0 "Assumptions and Limitations"

- No IPO/VOAT comments received for this ATBD

ATBD: Cloud Cover/Layers

ATBD#: Y2292

- No Watch List items related to this ATBD

- ATBD Sections
    - Abstract of ATBD – Needs additional information regarding heritage and current methodology.
    - Section 3.3.3 of ATBD – Delete.
    - Section 3.3.4 of ATBD – Should be moved to section 3.4.
    - Define output flags and their format in more detail.

- No IPO/VOAT comments received for this ATBD

ATBD: Cloud Effective Size and Cloud Optical Thickness

ATBD#: Y2393

- Watch list item 4 - Process for estimation of mean particle size from cloud top value may degrade CPS (Cancelled on 22MAR01)
    - Clarify in ATBD that the solution is a cloud top value.

- Section 3
    - Sections 3.4.1, 3.4.2 and 3.5.1 of ATBD – Replace multiple noise models with VIIRS sensor specification for noise.
    - Section 3.7 of ATBD – Specify validation data sets rather than simply listing possible ones.
    - Define output flags and their format in more detail.
    - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 5 Implement
    - 0 Advice
    - 5 Comment

ATBD: Cloud Top Parameters

ATBD#: Y2395

- No Watch List items related to this ATBD

- Section 3
    - Section 3.1.3 of ATBD – "Scenario parameters," indicated in Figure 2, should be specified.
    - Section 3.4.2 of ATBD – Replace multiple noise models with VIIRS sensor specification for noise.
    - Section 3.6 of ATBD – Specify the required validation data.
- Appendix A of ATBD – Determine need for this section
- Define output flags and their format in more detail

- No IPO/VOAT comments received for this ATBD

ATBD: Surface Albedo

ATBD#: Y2398

- Watch List item 6 - Albedo Neural Network (Cancelled on 22MAR01)
  - Conduct meetings with VOAT on this EDR, for the purposes of:
    - Clarifying why we chose this approach versus traditional approaches
    - Clarifying how training problems can be addressed
    - Determining if a hybrid approach can be employed as a baseline (done; switching to MODIS-like approach for dark surfaces)
    - Obtaining MODIS-and MODIS-adapted-to-VIIRS code, support from Boston University
    - Setting up an infrastructure within the VIIRS system design such that the solution for this EDR can be "plugged in" not long before launch of NPP
    - Establishing a plan for developing this EDR through EOS, NPP, and finally NPOESS

- ATBD Updates
  - Determine whether a viable training strategy for the neural net (bright surfaces) can be established based on existing and planned validation activities for MODIS, which has nearly identical bands to those used here
  - Add solar/viewing angles as inputs to the network, instead of binning by angle; this should reduce the burden of building a training database
  - Run simulations that test the neural net approach with an anisotropically reflecting surface
  - Define flags
  - Incorporate MODIS code as part of baseline algorithm
  - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
  - 0 Implement
  - 0 Advice
  - 1 Comment

ATBD: Land Surface Temperature

ATBD#: Y2399

- No Watch List items related to this ATBD

- ATBD Updates
  - Similar to those for SST, with the following additions:
  - Consideration to BRDF effects and shadowing
  - Refine strategy for handling of emissivity
  - Refine assessment of emissivity-related errors
  - Refine strategy for separating SST, LST, and IST operationally
  - Define flags
  - Improve readability of ATBD

- No IPO/VOAT comments for this ATBD

ATBD: Vegetation Index

ATBD#: Y2400

- Watch List item 5 – BRDF (Cancelled on 22MAR01)
    - Explore impact of adding another subproduct, an NDVI and/or EVI that has directional effects removed (coordinate with Monthly Vegetation Index product)

- ATBD Updates
    - Further refine strategy and ATBD description for Secondary Products, based on ongoing results from MODIS
    - Define flags
    - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 0 Implement
    - 0 Attempt
    - 1 Comment

ATBD: Snow Cover

ATBD#: Y2401

- Watch list item 5: Consideration of surface directional effects will better address EDRs based on solar reflective bands (Cancelled 22MAR01)
    - Plan to develop BRDF correction LUTs for snow prior to NPP launch
- Watch list item 7: Snow Cover EDR performance at large solar zenith angles and for various cloud cover and surface conditions (Cancelled 22MAR01)
    - Modification of Snow ATBD to adjust for BRDF
    - Facility to compute BRDF correction factors for various biomes incorporated into the Look Up Table generation tool (needed for snow fraction; desirable for ice concentration – possibly needed for snow binary map)
- Watch list item 8: Impact of cloud mask for EDR production and performance
    - System integration and specification issue

- ATBD Sections
    - Sections 3.2.2 and 3.3.3 of ATBD – include BRDF correction factors in the equations.
    - Section 4.2.1 of ATBD (Performance Analysis: Snow Binary Map) – Include analysis of MODIS validation data for snow binary map performance.
    - Section 4.2.2 of ATBD (Performance Analysis: Snow Fraction) – Include MODIS validation data for snow fraction performance.
    - Section 5.0 of ATBD (Initialization and Validation) – Plan for post-CDR use of MODIS validation data.
    - Define flags
    - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 1 Implement
    - 0 Advice
    - 4 Comment

ATBD: Surface Type

ATBD#: Y2402

- No Watch List items related to this ATBD

- ATBD Updates
    - Establish link to Earth Gridding in SDR module
    - Refine process for producing other Surface Type intermediate products
    - Refine requirements on input gridded products (e.g. Monthly Vegetation Index)
    - Refine tie-in with NDVI, Active Fires, and Snow Cover for instantaneous product
    - Define flags

- No IPO/VOAT comments received for this ATBD

ATBD: Ocean Currents

ATBD#: Y2403

- No Watch List Items related to this ATBD

- Section 3.0:
    - Operationalization tasks: criteria to determine what the cutoff day/time/location/cloud cover value for a pair of images to be processed
    - The type of regridding for ocean currents must be finalized
    - Automate MCC method, template parameters must be determined are not optimized.
    - Define flags
    - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 1 Implement
    - 0 Advice
    - 10 Comments

ATBD: Fresh Water Ice

ATBD#: Y2404

- No Watch List Items related to this ATBD

- IPO/VOAT Comment Summary
    - 0 Implement
    - 1 Advice
    - 3 Comment

ATBD: Ice Surface Temperature

ATBD#: Y2405

- No Watch List items related to this ATBD

- ATBD Updates
    - Similar to those for SST, with the following additions:
    - Refine assessments of errors due to emissivity differences, both spectrally and between different types/ages of ice
    - Verify that present strategy for dealing with these emissivity differences is sound and operationally viable
    - Coordinate with LST/SST for operations concept (i.e., where do we report IST and where do we report LST/SST)
    - Improve readability of ATBD
    - Define flags
    - Surface Temparature IP at imagery resolution

- IPO/VOAT Comment Summary
    - 1 Implement
    - 0 Advice
    - 4 Comment

ATBD: Littoral Sediment Transport

ATBD#: Y2406

- There are no Watch List Items related to this ATBD

- Section 3.0:
  - Automation tasks
  - Define flags
  - Define regions of applicability in greater detail

- No IPO/VOAT comments received for this ATBD

ATBD: Net Heat Flux

ATBD#: Y2407

- Watch List items:
    - MODTRAN versus 6S. A new LUT can be created based on MODTRAN. MODTRAN is a better forward model than 6S. However, it is much slower.

- Section 3.0:
    - Stability analysis is must be added to the algorithm, latent and sensible heat flux values depend on the stability between the air and sea surface temperatures, stability of the drag coefficient;
    - Define flags
    - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 1 Implement
    - 1 Advice
    - 1 Comment

ATBD: Ocean Color/Chlorophyll

ATBD#: Y2408

- Watch List items:
  - MODTRAN can be used in place of 6S for the forward model
  - Polarization issue will be addressed via monitoring of Vermote and Miami algorithms

- Section 3.0:
  - Investigate use of SST as an indicator of the degree of pigment packaging with VOAT assistance
  - Improvements to the atmospheric correction over oceans algorithm will in turn improve the ocean color retrievals;
  - Define flags

- No IPO/VOAT comments received for this ATBD

ATBD: Remote Sensing Reflectance

ATBD#: Y2389

- Watch List:
    - Strongly absorbing aerosols, turbid and shallow water retrievals, whitecap reflectance; all these deficiencies will be addressed

- Section 3.0:
    - Will attempt to address defenciencies in strongly absorbing aerosols, turbid and Shelton
    - Improve sections relating to polarization, scattering and sunglint processing
    - Define flags: SeaWiFS and MODIS flags
    - Sunglint flag with wind speed and geometry alone
    - Scattered light warning flag
    - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 1 Implement
    - 2 Advice
    - 2 Comments

ATBD: Sea Ice Age/Edge Motion

ATBD#: Y2409

- No Watch List Items related to this ATBD

- Section 3
    - Sections 3.2.1.6, 3.2.1.7, and 3.2.1.10 of ATBD (VIIRS Data) – Details on how these data will be acquired and maintained need development for version 5.
    - Sections 3.2.2.1 and 3.2.2.2 of ATBD (Non-VIIRS Data) – Details on how these data will be acquired and maintained need development for version 5.

- Section 4
    - Section 4.3 of ATBD (Practical Considerations) – Needs expansion.
    - Section 4.4 of ATBD (Initialization and Validation) - Use of MODIS validation data.
    - Define flags
    - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 1 Implement
    - 0 Advice
    - 3 Comment

ATBD: Mass Loading

ATBD#: Y2410

- There are no Watch List items related to this ATBD

- Section 3.0:
  - Define flags

- No IPO/VOAT comments received for this ATBD

ATBD: Surface Reflectance IP

ATBD#: Y2411

- Watch List items 2 and 3 (Incorporation of 3-D effects, Atmospheric forward modeling)
    - Monitor results of Lyapustin and Kaufman, switch to MODTRAN as baseline if appropriate, implement 3D solution if operationally viable and minimal impact on cost and schedule

- ATBD Updates
    - Make ATBD more readable
    - Establish LUT structure, coordinate with LUT generation tool development
    - Firmly establish quality flag structure (which is the basis for the quality control of other land products) and strategy for probably clear/probably cloudy conditions
    - Develop process for production of Weekly and Monthly surface reflectance intermediate gridded products
    - Define flags
    - Implement relevant IPO comments in Appendix A.

- IPO/VOAT Comment Summary
    - 0 Implement
    - 0 Advice
    - 1 Comment

ATBD: Cloud Mask

ATBD#: Y2412

- Watch List items:
    - Item 8 Impact of Cloud Mask on EDR production

- Section 3
    - Section 3.2.2 of ATBD –further development of this section (requires OMPS, CrIS, CMIS concurrent data).
    - Section 3.3.3 (and subsections) of ATBD –further development of this section.
    - Section 3.4.3 of ATBD claims that the VIIRS cloud mask will outperform the MODIS cloud mask are not sufficiently substantiated. VIIRS baseline is being reset to current MODIS technology.
    - Need a section on Practical Considerations.
    - Define output flags and their format in more detail.
    - Implement relevant IPO comments in Appendix A.
    - Using MODIS code and MODIS Science Team expertise, lock VIIRS Cloud Mask in step with current MODIS Technology, including spatial heterogeneity tests.

- IPO/VOAT Comment Summary
    - 13 Implement
    - 5 Advice
    - 10 Comment

ATBD: Precipitable Water

ATBD#: Y3251

- No Watch List items related to this ATBD

- ATBD Updates
  - Refine error budget, especially for cloudy conditions
  - Examine where this EDR can be used as an input to other EDRs, instead of analyses or CMIS data
  - Make ATBD more readable
  - Give further consideration to precipitable water in the boundary layer, which is not fully addressed by this algorithm as it currently stands
  - Develop quality flags

- No IPO/VOAT comments received for this ATBD

ATBD: Active Fires

ATBD#: Y3252

- Watch List item 12 - Development of Fire Algorithm
    - Already identified as part of normal work (see below)

- ATBD Updates
    - Incorporate NASA findings into algorithm baseline (already have some of this work)
    - Get with POCs to address Watch List item more thoroughly, establish a strategy for periodic algorithm coordination meetings
    - Provide much more detail in the ATBD on the actual structure and logic of the algorithm
    - Propose means of post-launch validation
    - Quality flags, strategy for using gridded products to characterize background temperature and vegetation cover

- No IPO/VOAT comments received for this ATBD

ATBD: RDR to SDR Conversion

ATBD#: Y3261

- Watch List item 10 (striping and calibration stability)
    - Work in close collaboration with SBRS and MODIS MCST personnel to develop destriping algorithm

- ATBD Sections
    - More depth on the input of the RDR, its format, and the extraction of calibration parameters from the data packets
    - Add detailed discussion of on-ground aggregation of dual-gain bands, which must occur after calibration to radiance
    - Generation of quality flags, which propagate through the rest of the VIIRS system
    - Update sensor-related information in Section 2 of ATBD
    - Need more info on the software issues in Section 3.5, including processing load and how calibration ties into other parts of the Build SDR Module
    - Need to coordinate this work with any calibration documentation provided by the sensor team.
    - Define flags

- No IPO/VOAT comments received for this ATBD

ATBD: Geolocation

ATBD#: Y3256

- No Watch List items related to this ATBD

- ATBD Sections
    - At each edit prior to a new version delivery, verify the sensor data and performance estimates are up to date by verifying with Dick Julian at SBRS.
    - Update heritage info from MODIS as it becomes available in V4 and V5 updates.

- No IPO/VOAT comments received for this ATBD

ATBD: Earth Gridding

ATBD#: Y7051

- No Watch List items related to this ATBD

- Build a skeleton ATBD for Version 4 delivery, containing all the sections and a top-level discussion of the described processes.
- Address the following gridded products:
    - Surface Type, Ocean Currents, Sea Ice Age/Edge Motion, Littoral Sediment Transport EDRs
    - Forest Mask, Surface Types¾Olson, and Surface Types¾Biomes IPs
    - Gridded Monthly Surface Reflectance, Monthly Brightness Temperatures, Weekly Surface Reflectance, and Monthly Vegetation Index, and Monthly Non-snow Reflectance IPs
    - Regridded Auxiliary Data
    - Regridded Ancillary Data
    - Include a discussion of how the VIIRS products in general map to Level 2 and Level 3
    - Describe the resampling process using heritage from MODIS and ETM+
- Obtain and adapt existing code if feasible
- Develop strategy for quality flags
- Development and documentation of the following products to CDR maturity:
    - Gridded Non-Snow Reflectance (for Snow)
    - Gridded Surface Type (for Snow)
    - Gridded Surface Air Temperature (for Sea Ice Age)
    - Gridded Ice Age Spatial Distribution (for Sea Ice Age)
    - Gridded Snow Depth (for Sea Ice Age)
- Define flags

- No IPO/VOAT comments received for this ATBD

APPENDIX A IPO/VOAT COMMENTS

Appendix to Algorithm/Data Processing technical Report

Appendix A is the record of comments given to Raytheon from the IPO VOAT in MAR01. Raytheon has analyzed the comments and determined three categories.

Implement. These comments contain information that is directly implementable into the VIIRS ATBD documents. These are shown in bold.

<u>Advice. These comments contain more general information that Raytheon will use as part of its ATBD updates, but which may not find direct placement in the document. These are shown as underlined.</u>

Comment. These are comments that do not require direct implementation or development of the ATBD. They are not corrections or enhancements. These comments may take the form of questions that will be answered in the text of the ATBD, or they may be statements of fact. Often the comments will be introduced into the body of the updated versions of the ATBDs. These are left in plain text.

The covering letter (via e-mail) from Major C. Welsch is attached below.

```
Rod & Pete,

Attached are the VOAT comments on the ATBD's.  I didn't want
to alter
the intent of their comments, so I've included them in their
entirety
(for the most part).  However, I don't want you (and neither
does Jeff)
to feel compelled to respond formally to each and every
comment.  You'll
find, in fact, that some comments are even contradictory.
We're
providing this material as informational material, and
expect you to use
your judgement in applying this to the Raytheon VIIRS
algorithms.  Let
me know if you have any questions.  Thanks.

Carol
```

From Alex Lyapustin, NASA

VIIRS Aerosol Optical Thickness and Particle Size Parameter

Algorithm over Land:

1. Unchanged Dark target method of Y. Kaufman based on 1-D theory of radiative transfer.

Comment: Over the dark targets used for aerosol retrieval over land, 3-D effects (blurring) systematically increase the apparent brightness, which is not taken into account in aerosol retrieval. This results in a systematic overestimation of the retrieved aerosol optical thickness using 1-D theory of radiative transfer. This error further propagates into a systematic underestimation of the surface albedo which in many regions of medium and high surface contrast may considerably exceed the tolerance of climate models (0.02).

The aerosol retrieval algorithm should take into account the contrast and spatial variability of the surface, and be dependent on pixel size.

Algorithm over Ocean:

Standard LUT approach.

Neglects: Water Leaving Radiance, White Caps and Foam (since it is spectrally independent).

Sun glints are supposed to be filtered from just geometric considerations (exclude area $\pm 30^0$ from sun direction. Compare: H. Gordon uses sun glint threshold mask for each pixel).

LUT is proposed to be calculated using 6S code, without detailed knowledge of the code accuracy.

Atmospheric Correction over Land

Algorithm: MODIS AC algorithm.

Comments: The AC algorithm is based on 6S code which has an approximate treatment of surface BRDF and 3-D effects, and of water vapor absorption (in the form of a separate layer placed either below or on top of aerosol layer). Its accuracy has not been studied to the full extent. Presently, 3-D effects, even in an approximate form, are not included in MODIS AC processing.

Surface Albedo

Main Algorithm: Neural network approach by S. Liang. It is supposed that using only spectral dependence of measured radiance, the neural network will “magically” eliminate effects of sun-view geometry (surface BRDF), atmospheric variability and 3-D effects due to surface nonhomogeneity. The error budget is studied only in 1-D and Lambertian approximation, which essentially eliminated most of the albedo variation.
Secondary Algorithm: Is suggested but not studied and developed.

VIIRS Vegetation Index (VVI)

The proposed top-of-canopy vegetation indices will be subject to the errors of atmospheric correction which are essentially unknown. Our recent study showed that unaccounted 3-D effects alone (due to surface inhomogeneity) may result in error twice as large as the threshold requirement. (The atmospheric blurring has a significant effect on the normalized difference vegetation index (NDVI) which is used in studies of the land bioproductivity. Since the blurring increases the reflectance of vegetation in the red wavelengths where vegetation is dark, and decreases its reflectance in the near IR where vegetation is bright, the remotely sensed NDVI might be severely underestimated in ecosystems characterized by a homogeneity scale of less than several kilometers).

From Larry Stowe, NOAA:

CLOUD MASK ATBD (Y2412):

SUMMARY:
Approach and ability of that approach to separate clouds from aerosols (haze, smoke, dust) not explicitly stated in the ATBD. Also, the VIIRS cloud mask has no tests based on spatial uniformity, although they indicate that future studies will be conducted to explore its value.

RELEVANT DETAILS:
P. 14: **Expect to eliminate heavy aerosol by calling it cloud. Will adversely impact Suspended Matter EDR.**

P.23: **Non-cloud obstruction test talks about flagging heavy aerosols for analyst, but not about how this will be done automatically in a cloud mask for aerosol and suspended matter EDRs.**

AEROSOL OPTICAL THICKNESS ATBD (Y2388):

SUMMARY:
Does not describe the retrieval of AOD over ocean in much detail: states a simultaneous solution of AOD and size parameter, using first guess to estimate suspended matter, which allows selection of another aerosol model from first guess. No iteration between these two algorithms is proposed. There are no details as to size distribution models or the retrieval methods used. Their retrieval of effective particle size (an objective requirement) does not attempt to reconstruct the particle size distribution, as is done with the MODIS aerosol algorithm, but rather depends on a statistical regression technique.

RELEVANT DETAILS:
AOD, P. 8: A quality flag will be assigned to indicate when cloud contamination may be present in AOD, but there is no clear explanation of how this is done.

AOD, P.12: Describes contents of pixel quality flag, which is much like MODIS cloud mask, with probability conditions of cloudiness coded in the flag, but no information on what amounts or thicknesses of cloud cover constitute contamination of clear-sky pixels.

AOD, P.13: **Land algorithm is based on MODIS dark pixel approach. Also suggests that UV reflectance be used, although, no UV channels proposed on VIIRS. Uses continental aerosol model as first guess, then uses**

suspended matter retrieval, to chose better model for retrieval. But no mention of the form of the size distribution model or how sensitive the accuracy of the retrieval is to this form.

AOD, P.15: **ATBD uses Suspended Matter EDR to type aerosol for selection of model for retrieval of AOD over ocean and land. Also propose using aerosol index from OMPS to separate aerosols into absorbing and Non-absorbing. Also note that marine aerosol used over ocean, and iterative approach used to select most appropriate aerosol model for retrieval, but again no details of form of model and retrieval sensitivity to it.**

AOD, P. 18-19: **Proposes to use empirical relationship found at AERONET sites between effective particle size and Angstrom exponent. I think they should attempt to do an effective particle size based on a bi-modal aerosol model like that for MODIS or one that is selected from the suspended matter EDR, based on blue, green and red AODs from VIIRS.**

SUSPENDED MATTER ATBD (Y2390):

SUMMARY:

No new information about cloud mask separation from aerosol is presented. However, the suspended matter algorithm is only applied when pixels are identified as cloud-free. Yet there are spectral tests in the suspended matter ATBD that are sensitive to the differences between cloud and aerosol reflection. Thus, it seems that some of these tests should be incorporated into the cloud mask EDR, so that cloud-free pixels can be passed onto the algorithms for both AOD and suspended matter EDRs. Some of the suspended matter indices are derived from AOD and ASP (aerosol size parameter) initial estimates, so cloud-free pixels must be delivered to the aerosol retrieval package as well. The aerosol type is determined primarily by the Angstrom exponent. However, there is no error analysis to show how accurately this parameter can be measured, and how that accuracy depends on the amount of aerosol (optical depth) in the vertical column. Also, it seems that better accuracy could be achieved if there were several iterations between the AOD and ALPHA EDR algorithm and the Suspended matter EDR algorithm, to converge on the optimum solution for all aerosol parameters.

RELEVANT DETAILS:

SM P. 4: The narrow band measurements of the VIIRS sensor in the 0.4 to 3.70 □m range are used to derive aerosol optical depth, which is then used directly in the identification of suspended matter. The visible and near-IR channels used to derive optical depth are all within window regions, and their bandwidths are narrow, so that the contamination of gas (such as O_2, O_3, H_2O) absorption is minimized in direct measurements. The suspended matter algorithm uses techniques involving not only visible and near-IR channels, but also four IR channels (3.70, 8.55, 10.8, and 12 m). Aerosols display strong spectral variations in these thermal spectral regions, and the atmosphere is also fairly transparent here. Thus, the signature of the aerosol emissions will be detectable by the sensor, especially when the aerosol loading is thick.

SM P. 12:
Marine aerosols affect radiative transfer and climate directly by scattering and absorbing radiation and indirectly by influencing the droplet size distribution and albedo of marine boundary layer clouds. Thus, sea salt as a primary component of coarse marine aerosol particles plays an important role in radiative forcing. Sea salt will be differentiated from the other types of suspended matter using size distribution and geographic location. Sea salt is composed primarily of sodium and chlorine and is injected into the atmosphere when air bubbles on the surface of the ocean burst in breaking waves. Sea salt has a unique size distribution that can be used to distinguish it from other possible suspended matter. Sea salt particles have an Angstrom exponent greater than 0.0 and less than 0.5 and the optical depth is usually less than 0.15. Dust has same Angstrom exponent range bu AOD >0.15.

SM P. 14: **Smoke particles are small particles with an Angstrom exponent greater than 1.4 and exist at optical thicknesses greater than 0.5. The physical basis of the smoke index is that SeaWiFS channel 1 (412 nm) reflectance (or radiance), R1, is sensitive to both smoke and cloud particles. However, the reflectance of channels 2 (443 nm), R2, and R4 (510 nm), R4, as well as on channels R5 (550 nm), R5, and R6 (670 nm), R6, is uniform (R2_R4= 0; R5_ R6= 0) for clouds but different (R2_R4>0; R5_R6>0) for smoke. Thus, the combination, R1x (R2_R4)x(R5_R6)x10000, is close to zero for clouds but much larger than zero for smoke, creating a smoke index.**

SM pp. 27_28 (tables 4&5): <u>Type of aerosol related to AOD and Angstrom exponent (ALPHA) from first guess retrievals. The aerosol type is determined primarily by the Angstrom exponent. However, there is no error analysis to show how accurately this parameter can be measured, and how that accuracy depends on the amount of aerosol (optical depth) in the vertical column. Perhaps the approach being used in MODIS retrievals over ocean, where the relative concentrations of the two modes of a bimodal size distribution is varied to match multi-spectral reflectance measurements, is a more robust way to identify aerosol type. Also, there should be several iterations between the AOD and ALPHA EDR algorithm and the Suspended matter EDR algorithm, to converge on the optimum solution for all aerosol parameters.</u>

OTHER ISSUES INDIRECTLY RELATED TO THE ABOVE ATBDs:

In the SST algorithm error budget, no allowance is given for using the wrong aerosol model in correcting for aerosol effects. Nor is volcanic aerosol used in the error assessments, which causes the largest aerosol induced error in SST because of its being in the "cold" stratosphere. Also, how the aerosol type is provided to the SST correction algorithm was not presented.

The relative calibration (uniformity) between (16 or 32) filtered detectors in focal plane arrays for each channel needs to be carefully monitored to meet instrument specification. This is important if spatial uniformity tests are to perform well on 2 scan-line by 2 pixel arrays in the cloud mask EDR. It is also an important specification to avoid striped images which are difficult for analysts to interpret.

From Andy Heidinger, NOAA:

Y 2412 Cloud Mask ATBD

The cloud mask algorithm applied here is a pixel scale multi-spectral threshold approach. This algorithm should work well and the channel available to VIIRS should allow for this algorithm to be successful. There are some minor concerns with the ATBD as it stands now.

Table 6 There is no test attempt to screen clouds from aerosol. In AVHRR, 3.7 or 1.6 micron reflectances have been used to perform this task during the day. There is no mention of a VIIRS cloud mask test dedicate to this effort.

Table 6 - Use of the 1.6 micron threshold over the desert. From NOAA-16 experience, the 60% threshold is probably too low for some deserts. With such a high threshold, this test is redundant. Some work has shown that 1.6/0.65 ratios are useful but this is to be determined. I think it most prudent to exclude a direct use of 1.6 micron reflectance test over the desert.

Table 6 Spatial uniformity needs to be included. This is probably debatable, put there is extensive evidence to warrant the use of spatial variability as an additional cloud test. How this effects the definitions of confidence needs to be addressed.

3.3.5.4-5 The descriptions of the cloud mask in Polar and Snow/Ice regions seem focused on the day-time procedures. Please include the night time basis for this algorithm in these regions.

3.3.4.4 Cloud Phase
There is mention of a cloud phase algorithm to be contained within the VIIRS cloud mask.
There is also a mention of a UCLA cloud phase algorithm in the Cloud effective particle size and
optical depth ATBD. Which is the VIIRS cloud phase product? Where is a listing of its performance in this ATBD?

3.2.2 - Other ancillary data are said to be useful. When and how will this decision be made as to if they are in fact useful and will be included in the cloud mask algorithm?

Y2393 Cloud Effective Particle Size and Cloud Optical Depth ATBD

The team developing this algorithm are leaders in this field. There are a few comments concerning the implementation of this algorithm in the VIIRS system.

Figure 2 - This figure hints that the cloud phase algorithm is part of this ATBD. While the cloud mask has its own cloud phase algorithm. Which is correct?

3.2.1.4 - The cloud mask is a four-tier product. Which cloud mask values are considered cloudy enough for this algorithm? For example, is probably cloudy used in this algorithm?

3.3.3 Are there any attempts made to screen partly cloudy pixels from influencing the compositing used to make the final products which have a resolution of 25 km ?

From Andy Harris, NOAA:

SST ATBD

p.3, para 2, l.6,7 Accuracy of operational SST is now about 0.5 degK r.m.s.. This may not seem a significant change, but it represents a reduction of 50% in terms of independent error sources.

-,-,l.14,15 It should be acknowledged that inclusion of water vapor information (e.g. the Emery et al. paper) has yet to prove beneficial in a statistically significant sense. However, the use of transmittance information (Harris & Mason, 1991) has been demonstrated to be beneficial. Apologies for referencing my own paper, but it is the reference I know best on this topic.

-,-,l.15-18 I assume that physical retrieval means non-linear, iterative (a.k.a. variational) retrieval. However, radiative transfer methods of generating linear regression equations are also physical, as indicated in paragraph 2 on the next page. Perhaps they should use the term 'variational' since there is relatively little cost in the latter approach.

-, para 3. This is a key paragraph in terms of understanding the ATBD. I say this because it is important not to place too high a weight on the skin-bulk difference, especially at night. There are a few terminology problems, and, in my view, some important omissions:

-,-,l.1 satellite sensors _measure_ top-of-atmosphere radiance. An algorithm is required to retrieve skin temperature of the ocean from the measured ToA radiances. Note that this retrieval will have
varying accuracy depending on conditions.

-,-,l.2,3 It is important to say why most scientists (not just oceanographers) are interested in bulk temperature. There are 2 main reasons: 1) The bulk temperature is representative of the heat stored in the mixed layer (remember the skin layer has virtually no heat capacity in comparison) and available for exchange with the atmosphere; 2) traditional measurements of SST have been bulk (buckets, buoys, ship intakes). The latter is important when trying to blend satellite and in situ SST data.

-,-,l.7 The work by Schuessel et al. is at variance with virtually all other skin effect parameterizations, going back to Saunders (1967). I shall discuss this more later.

-,-,l.9,10 Again, ATSR retrieves skin SST. Also, I believe the correct reference is Zavody et al. (1995).

p.4, para 2, l.3,4 Note that the apparently demanding instrumental and model requirements have been met with ATSR, which was launched in 1991, i.e. nearly two decades before VIIRS is due for launch. Also, it is worth stating that the requirement for low sensor noise has been over-stated. There are techniques for overcoming pixel-level noise problems (e.g. Harris & Saunders, 1996).

-, para 3, l.3-7 The requirements only exceed current state-of-the-art operational results in terms of horizontal resolution, and this is only because of the ancient recording and on-board processing technology of the AVHRR. ATSR NRT SST, which could be considered operational, has far better accuracy, and is available anywhere (but not everywhere) in the world at 1-km resolution. Quoting the global warming trend over a decade points the finger at stability of the entire retrieval process, from calibration of raw radiances, through cloud masking and the calculation of SST from radiances.

p.6, Table 2, Is it really the case that a 29 cm mirror only achieves an NEdT of 0.12 degK at 3.7 um, 300 K target temperature? I know the filter width is only 0.2 um but the mirror is huge (relatively speaking). Table 3a (next page) shows a much more realistic value of 0.065 degK.

p.7, para 2, l.2 CrIS will not be available. The best source of 1st guess H2O and T profiles for variational retrieval would be a 6-hour forecast field, which will have used CrIS data (and AMSU, IASI, etc.) from the previous 6 hours.

p.9, Figure 3. The flowchart has the cloud masking procedure omitted.

p.10, para 1: The cloud mask is a required input here, but there are also requirements for cloud opticxal thickness, aerosol optical thickness and aerosol type that are unlikely to be available in time, unless the ATBD refers to products derived from an external source. Paragraph 2 indicates that this is not the case.

p.13 Inclusion of scattered solar radiation in the calculation is an unnecessary complication that makes Figure 5c unnecessarily difficult to interpret.

p.14 I strongly object to the suggestion that the reflected term is negligible, particularly at high zenith angles. Also, it would be appropriate to reference the derivation, which is to al intents and purposes, that of Deschamps & Phulpin (1980).

p.18, para 2, l.1 Emissivity is not uniform. It changes with view angle and wavelength. I assume that this has been taken into account in the simulations.

-, para 3, l.4 Again, the work by Emery et al. demonstrated no significant improvement (although inclusion of such information does have the potential to improve the retrieval if done in the correct way).

p.19, para 1, l.4,5 It is not necessary to have global skin SSTs in order to validate to the required accuracy of the EDR. What's needed is to consolidate the existing skin effect data to produce a reliable equation for delta-T = F(u*, Q*, SST). Then it is possible to validate against in situ bulk SST.

-, Equations: It is not necessary to prescribe the zenith angle in the retrieval. Using radiative transfer, it is possible to obtain retrieval coefficients for a selection of airmasses (sec(Z)) as in Llewellyn-Jones et al. (1984). Also, the water vapor algorithm makes, as can be discerned, rather unambitious use of the extra information. Note that (16) can simply be recast as SST = a0 + a1'T11 - a2T12 + a3(sec(Z) - 1) +a4wat, where a1' = a1 + a2. This helps to dispel the notion that there is something special about subtracting one band from another.

p.20, Equations: Note that (22) is exactly the same as (16). I would be very surprised if the quadratic term in (21) added anything to the result. Also, the term non-linear SST, for operational use, means that there is a first-guess surface temperature used in the retrieval from the previous analysis. This seems to be absent from all equations.

p.23, Para 1, Accuracy of split-window NLSST is now about 0.5 degK r.m.s..

-, para 2 Not really so, the main concern is biases, particularly those exhibiting a secular trend (e.g. calibration drift, sensor changes, aerosol events, esp. volcanic). Important to distinguish between point accuracy and monthly mean accuracy. What is the reference for the 0.2 K heat flux requirement?

-, para 3. While I do not dispute the Susskind reference, the original would be Rogers, 1976. Also, some physical retrieval methods have been applied to AVHRR (e.g. Steyn-Ross), albeit not very rigorously in their case.

-,para 4-6 What is alpha?

p.24 It is worth saying that A is the Jacobian matrix.

I'm running out of steam (and I've only got about 1/3 of the way through the document) so I'll just finish off with a few general comments. There is a recurring theme of the need for global validation of skin SSTs from in situ autonomous radiometers mounted on ships-of-opportunity. While such information would be nice, it is not essential. As an example, the latest SST retrieval algorithms for ATSR (Merchant et al., 1999) have achieved bias and scatter results of <0.1 degK and 0.25 degK r.m.s. against TAO buoys (Merchant & Harris, 1999) with no empirical tuning. Note that these validation results were obtained under exceptionally difficult conditions when Mt Pinatubo aerosol burden was high and operational algorithms were experiencing erros of 2-3 degK. No in situ radiometer measurements have contributed to the development of these algorithms. Interestingly, the use of the Schluessel formulation for skin-effect delta-T demonstrates a lack of critical investigation, since it is completely at variance with the majority of work in this area. For example, Saunders' (1967) formulation is:

$$\text{delta-T} = \text{lambda}\ \frac{Q\ v}{K\ u^*}$$

which says, in effect, that the temperature drop aross the conduction layer is proportional to the heat flux through the layer (Q) divided by the conductivity (K) times the thickness of the layer, which is a function of the viscosity (v) divided by the surface friction velocity (u*). In short, as windspeed goes up the skin layer thins, so the path length of resistance to heat flow decreases and delta-T drops. Concomitantly, when net heat flux increases (holding u* constant) the 'current-flow' through the resistance increases and a larger potential difference is required, i.e. delta-T increases. This basic formulation has proved to be very successful. Fairall et al. (1996) produced a blended version of the above equation and Saunders' one for free convection (note the equation would become unstable as windspeed approached zero) which has been used by myself and others with success. The equation of Peter Schuessel (which I don't think he would stand by now) is essentially a version of the bulk formulae for latent and sensible heat flux - i.e. only accounting for the increase in delta-T with increased net heat flux, and not the decrease due to thinning of the conduction layer.

A couple of other areas I am concerned about are the lack of discussion of the radiative transfer models that will be used and the spectral data (esp. water vapor continuum) that will be used. This is vital for a single-view instrument. Also, there seems to be little understanding of the large effect that volcanic aerosols of very small optical depth (0.01 @ 12 um, or approx. 0.1@0.55 um) can have on the retrieval, and that the 8.6 um channel is a powerful tool in combating such effects. Additionally, I did not see any discussion regarding the assignment of error terms (e.g. off-diagonal, to account for thin cirrus, or other contaminants). In fact, the whole subject of the importance of fully characterizing the error matrices for observation, background and forward model seemed to be lacking. Finally, I was not convinced of the the existence of a mechanism that is needed to move from validation to improved algorithms.

From Eric Shettle, NRL:

SBRS #2386 SST

* Page 71, Sec. 3.4.4:
The aerosol correction depends on:
  (1) The difference between the Temperature of the aerosol layer and the SST [or the height of the aerosol layer]
  (2) The aerosol single scatter albedo
Are the full range of these included in the "aerosol training set"

* For near grazing incidence the emissivity of the water surface will deviate significantly from 1, especially with high winds [& rough seas]. There does not appear to be any correction for this effect when looking towards the edge of scan?   By my calculations this is a 5% effect at a 40 to 45 degree angle from normal incidence and 10% at 50 degrees, depending on wavelength.

SBRS #2388 Aerosol Optical Thickness & Particle Size Parameter

* Page 5, Section 2.3.2:
What is the status of the use of the near UV channels from OMPS?

* Page 10, Sec. 3.2.2.3:
Reflectance of Foam spectrally dependent

* Pg 12-13, Sec. 3.3.2.2:
The use of "half of the precipitable water" to correct the TOA radiances for water transmission assumes the effective scale height of water vapor is similar to that of aerosols & Rayleigh scattering. This is a questionable assumption.
Why not use $T_g(O_3, M) = \exp[-a (M^*O_3)^b]$?
I would expect b ~ 1. Beer's law works fairly well for ozone.
How are the coefficients for the water and ozone transmission derived?

* Page 13, Eq. (4):
For total [aerosols + molecular] optical depth > ~ 0.5 the assumption of single scattering breaks down, and Eq. (4) is no longer valid.

* Pg 15, Sec. 3.3.6.1:

What are the various aerosol models that are included in the LUTs? Do they encompass the full range of possible conditions and aerosol types.

* Pg. 16-19, Sec. 3.3.7.2:

Why use just a single pair of wavelengths to derive effective radius? How well would it work to use r_{eff} from the models used for the LUT? How do these AeRoNet size distributions relate to the models used for the LUTs? If you used these AeRoNet size distributions to generate the TOA radiances, how well does your algorithm reproduce the correct Ånström coefficient & effective radius?

* Sec. 3.4:

The aerosol sensitivity studies should start with non-standard aerosols that differ from the models included in the LUT forward calculations.

* Pg 31, Sec. 3.4.4:

Aerosol with a significant component of particles > 1 micron, [such as oceanic or desert dust], can have a significant AOT at 2.25 microns, [the Bahrain desert aerosol in Fig. 3, probably has AOT at 2.25 comparable to the values in the visible].

* Pg. 35-41, Sec.3.6.1:

Pre-launch verification should include MODIS data.

** This ATBD does NOT contain sufficient detail to actually write a computer code.

SBRS #2389 Atmospheric Correction over Ocean

Page 15, lines 4-12:

A potentially more serious consequence of neglecting the spectral dependence of whitecaps, is errors in the albedo at 751 & 858 nm become compensating errors in the derived aerosol optical depths which are then extrapolated into the atmospheric correction at the shorter wavelengths.

Page 19-24, Sec. 3.4.3:

In addition to stray light problems near areas of significantly different albedos, there are adjacency effects that require 3-D radiative transfer models to model appropriately. That could effect all the simulations in this section.

Page 30:

The single scattering albedo depends on what properties you assume for the desert aerosols. While d'Almeida (1991) et al. have ~ 0.8 in the visible, for the Longtin et al. (1988) model the single scattering albedo varied from ~ 0.98 to 0.99 for no winds, ~ 0.93 to 0.96 with 10 m/s winds, and decreasing to < 0.8 with

30 m/s winds. This dependence on wind speed is due primarily to the increase in the characteristic particle size with increasing winds. Given these largest particles will settle out as the desert aerosols move over the ocean, this would suggest single scatter albedos > 0.9 might be more appropriate.

Page 33, Sec. 3.6:

It is recommended that the error budget include the effects of the aerosol present not being represented by any of the standard models you are using. Keep in mind that most models are developed to represent "typical" conditions not the extremes.

Page 33, lines 10-11:

"The following error budget tables …" are missing.

SBRS #2390 Suspended Matter

Section 2.3.2, Page 7-8:

Most of the references cited here are missing from the List of Reference [pg 39-40]. A number of the other references are also missing.

Section 2.3.2, Page 8-9:

You should be cautious about relying on the Longtin et al. (1988) desert model [or any single aerosol model] to predict the spectral characteristics of the brightness temperature differences. Ackerman (1997) noted that while the Longtin et al. desert aerosol model produced realistic values of BT_8-BT_{11}, it did not produce realistic values of BT_{11}-BT_{12}. Conversely he noted that an alternate desert model developed by Koepke et al. produced realistic values of BT_{11}-BT_{12} but not BT_8-BT_{11}. He suggested the fact that both of these models made the simplifying assumption that the sand particles are spherical could account for some of their difficulties in reproducing the observation

Page 21, Sec. 3.3.7:

The Ångström exponent of sea salt type aerosols can exceed 0.0, and the optical thickness can exceed 0.15, especially with [or shortly following] high winds. More critically neither test will uniquely distinguish sea salt type aerosols from desert dust/sand.

Page 21, Sec. 3.3.8 & 3.3.9:

Both of these tests for smoke are sensitive to any type small aerosol particles, which, includes most of the aerosols that are the result of gas-to-particle conversion processes. The sulfate and nitrate aerosol particle both from air pollution and some natural sources, are one example of the latter.

Page 22-23, Sec. 3.3.11.1:

In Eq. (1) the value of "1000" is empirically based and is strictly valid only for a specified composition and size distribution.

Iqbal's (1983) Eq. (6.6.2), which is presumably the basis of your Eq. (2) is mixing apples & oranges. The correct form of Eq. (2) from the definition of Meteorological Range, V, in terms of the aerosol extinction coefficient at 0.55 microns, k, is:

$$V = 3.912 / (k - 0.012)$$

Where $k = \beta / 0.55^{\alpha}$ from Ångström's turbidity formula, and the 0.012 is the correction for Rayleigh scattering at the surface for a standard atmosphere. The Ångström coefficient, β, is the aerosol extinction at a wavelength of 1 micron.
In going from Eq. (2) to Eq. (3), you equate the aerosol optical thickness [AOT] with the aerosol extinction coefficient, which is valid under a few limited conditions such as all the aerosols are uniformly mixed in the lowest 1 km of the atmosphere or have an exponential scale height of 1 km. Note you might be able to approximate the AOT as function of the aerosol extinction, k, [or the Meteorological Range, V] with a function of the form:

$$AOT = a*k + b$$

Where *a* depends on the vertical extent of the atmospheric boundary layer, and the vertical distribution of the boundary layer aerosols, and *b* would be the optical thickness of the aerosols in the free troposphere and stratosphere above the boundary layer. This would lead to expressions similar in form to your Eq. (3) & (4), although with different values for the numerical constants. Also see Longtin et al., [D.R.Longtin, E.P.Shettle, & J.R.Hummel, "A Technique for Estimating Surface Meteorological Ranges over Oceans From Satellite Measurements of Aerosol Optical Depth, AFGL Tech. Rep., GL-90-0284, 16 October 1990].

<u>Page 23-26, Section 3.3.11.2</u>:

I would think large amounts of any small particle aerosols [with Ångström exponents much greater than 1], would produce large values of your Smoke Index, SI, in eq. (5).

Whether smoke appears white or gray or black, will depend not just on the optical depth, but also on the relative amounts of ash and condensed water vapor. Significant amounts of condensed water vapor can increase the characteristic size of the smoke particles, thus reducing the SI.

When you only have five different optical depths, τ, used going into the calculations used to fit SI as a function of τ, using five parameters in Eq. (6) seems like over kill.

<u>Page 27, Table 4</u>:

<u>You will get desert aerosols with AOT < 0.15, and maritime aerosols with AOT > 0.25. So you will not be able to distinguish the two types based on AOT. Looking at the IR characteristics as you discuss in section 2.3.2, might help [with the caveat noted above].</u>

For Continental aerosols [or almost any other aerosol type] with $\alpha > 1.4$, I would expect SI > 0.

Page 28, Table 5:

You should recognize that d'Almeida, WMO-112, and LOWTRAN do not represent independently developed aerosol models. WMO-112 was based in good part on an early version of the LOWTRAN models, and d'Almeida et al. in turn based some of their models on WMO-112 and the LOWTRAN models.

Also WMO-112 does not have a "Biomass Smoke" aerosol. While it has a "soot" model, that was intended to represent the Soot Component of their Urban/Industrial model.

SBRS #2407 Net Heat Flux

Page 30, Eq. (16) and 2nd line following Eq. (16):

Presumably that should be τ_{MW} not τ_{MV} in Eq. (16)

"The total transmittance of he atmosphere, τ_{MW}" NOT "ε_{MV}"

Page 31, Eq. (19):

The wind speed term in this approximation to the surface albedo from Hansen (1983) only corrects for the surface roughness effects. It does not include changes in the ocean albedo due to the generation of white caps or foam.

Page 37, "a. forward model":

An estimate of the accuracy error in the forward model at least for SW flux could be obtained by comparing 6S with MODTRAN. Similarly in the next section on "atmosphere correction" the error in the multiple regression can derived by comparing the regression results with MODTRAN and 6S.

Comments on VIIRS Error Budget [from SFR June 1999]

Note – These comments were in my notes from the SBRS SFR June 1999. I do not know if they are still valid. I would like to see the current version of the detailed error budget to make sure there are no other potential problems. The list below was not necessarily comprehensive, so there might have been others.

Page VIIRS-SFR-110:

The approach in analyzing the detailed Error Budget is good, but some of their estimated errors are wrong. Assigning a 0.0 error to missing thin cirrus in the cloud mask, since the thin cirrus will just be added to the column aerosol optical thickness [AOT], is not completely satisfactory. While for some applications such as atmospheric corrections treating thin cirrus as aerosols will yield acceptable results, for the aircraft relying on their IRST system to see targets or hostile aircraft through the thin cirrus which they were expecting to be aerosol [and probably at a lower altitude], it would not be satisfactory.

The estimated contributions for the uncertainties of the ozone absorption coefficients to the Error Budget are too small. Around the peak of the Chappuis absorption band [520 to 800 nm], the uncertainties are 1 to 2 %. For a typical ozone column amount of 300 DU [normal range 100 to 600 DU], this would correspond to an uncertainty of 3 to 6 DU, not the 1 DU they give. At longer and shorter wavelengths the relative uncertainties become much larger, approaching 25 % near 450 nm, [or 75 DU]. However because of the decrease in the magnitude of the ozone absorption at these wavelengths the resulting effect on the Aerosol Optical Thickness [AOT] will less. It also should be noted that least for AOT, even with the more realistic uncertainties on the ozone absorption coefficients, their contribution to the total error budget is relatively minor. For other EDRs where they do not provide a similar detailed breakdown of the error budget, this under estimate of the uncertainties in the ozone absorption coefficients, may not have as minor an impact on the total error budget. Similar remarks could also be made on the estimated uncertainty in the water vapor absorption coefficients.

From Tom Kopp, AFWA:

Imagery ATBD (Y2466)

p.11 2.4.3.1 The models FIVLYR and TRONEW were replaced by a new forecast model in December, 1996 called Advect Cloud (ADVCLD). ADVCLD can be thought of as an advanced, global version of FIVLYR.

p.14 2.4.3.3 The last paragraph refers twice to sections "xxxx". These sections were to discuss cloud detection of certain types. There is some discussion in that regard later in the ATBD but it the section referred to by xxxx remains unclear.

p.30 3.2.4 This paragraph refers to earth curvature correction (p.xi in the introduction does as well) but there is no description in any document, including the Geolocation ATBD, how this is done. Here at AFWA we employ an earth curvature correction to the imagery itself for display purposes, but it is not clear that is meant by section 3.2.4. Please add a description, in whatever is the appropriate ATBD, how earth curvature correction will take place. Given the context, we do not believe the earth curvature correction mentioned here is the same as what we are doing at AFWA.

p.42 3.3.6.3 This short paragraph implies there will be comparisons with the "heritage OLS technique". Just what aspect of the OLS technique is being referred to in this section? Note that we (AFWA) are investigating a Gain Management Algorithm in use by DMSP for possible inclusion in VIIRS. Is that part of the heritage technique?

From Doug May, NAVO:

SST ATBD

NPOESS will be an operational satellite. I found the overall discussion within the SST ATBD to lack a day to day operational focus with too much emphasis on long term global climate change. The very last sentence of Section 2.1 suggests that weekly global SST fields are the primary purpose of generating satellite SST retrievals from NPOESS. I disagree, the NPOESS SST EDR must support both the short term operational analysis/model needs and the long term global climate change needs. Operational DOC and DOD agencies require operational daily SST fields to support atmospheric and oceanographic analyses/models that run every 12 to 24 hours. Most of these daily SST analyses currently update every 12 to 24 hours using only the last 24-48 hours of SST data. Daily model atmospheric planetary flow predictions are affected by SST in the tropics and subtropics. In addition, daily atmospheric convection is sensitive to SST changes in the tropics. Operational daily forecasts are therefore highly dependent upon accurate SST data.

Validation of the SST EDR has to address a bulk validation process because present operational DOC and DOD analyses/models use the bulk SSTs. The authors are assuming that atmospheric and ocean modelers will no longer be using bulk SSTs when NPP flies in 2005. This assumption may be risky. Perhaps the best option is for NPP to provide both skin and bulk SSTs with validation for both.

The authors have not addressed whether they will process SSTs at full one pixel spatial resolution or whether they will use arrays of data (both across scan and along scan) and degrade the spatial resolution to an unspecified value.

A simple system flow diagram is needed for the inputs into each term of the SST equation and the inputs into each of the cloud mask tests. Such diagrams would readily help us to identify the effect of changes to the instrument on the SST algorithm implementation.

3.1, page 9 – Where will ancillary data sets be obtained? Does a government agency need to provide these?

3.1, page 9, Figure 3 – The phrase “(or blended SST)” listed under Skin SST mysteriously appears without being defined or described in preceeding pages.

3.2.2, page 10 – Who will provide the observed skin and bulk SSTs?

3.3.2.1, page 20 – Authors need to demonstrate that a second order polynomial equation is needed. Does stepwise regression show statistical significance for a second order term relative to the other terms in the equation?

3.3.4, page 24-35 – The authors do not clearly state what specific data sets they are using when. The figures appear to jump from one set of data to another without clear explanation. The authors also do not state clearly how the different data sets were obtained. This is an important point that needs to be clarified.

Figure 14 – The 5-15C data clearly performs the best. The 25-30C data is cold. The 15-25C data is both cold and warm. Clearly the results are driven by the range of the data and the number of data points within various sections of that range. This fact overrides any other conclusions that can be made about the performance.

Page 27 – The relative radiometric error is large at low SST because of the low sample number at low SST. This is a key point. Basically, all of the statistics discussed here are relative to the number of samples existent within partitions of the total range. This fact overrides all other conclusions that can be made.

Figure 18 – How were the snapshot SST and retrieved SST obtained and from where?

Figure 19 – How did the authors match satellite zenith angle with global surface data? It is not explained.

3.3.4.2, page 35 – The statistics discussed were calculated relative to what truth SST, the Kalnay data?

Page 74 – It is not clear to me what the authors did or how they did it. The results demonstrate improvement, but the steps taken are very difficult to follow. Can the aerosol type method be used to correct SSTs at night? If not, then what should be done at night? No visible reflectance channels have useful data at night. This solution is not adequate if it isn't applicable to all 24 hours of data each day.

Figure 61 – This figure is used to determine that cloud contamination should be less than 5% in order to obtain acceptable SST accuracy results with the quad algorithm. However, in sunglint conditions, the split window algorithm must be used and the figure shows that the cloud contamination must be less than 2-4% for accurate SST to be retrieved. This is an important point because cloud detection in sunglint regions is very difficult. The authors need to state what confidence they have in sunglint

cloud screening and what confidence they have in SST retrieval accuracy in sunglint.

Comments on Cloud Mask ATBD

VIIRS will be an operational sensor on an operational satellite (NPOESS). Therefore, an operational cloud detection scheme is critical to the accuracy of all VIIRS derived EDRs. For the purpose of retrieving SST, the cloud detection tests described in the Cloud Mask ATBD may not adequately detect all clouds that can affect SST retrieval accuracy. Specifically, there are concerns that low level, relatively warm stratiform and scud clouds over the ocean at night will be misinterpreted as clear ocean pixels by the cloud detection tests proposed. In addition, sub pixel clouds and cloud edges may not be adequately detected by the proposed Cloud Mask tests.

A simple system flow diagram is needed for the inputs into each term of the SST equation and the inputs into each of the cloud mask tests. Such diagrams would readily help us to identify the effect of changes to the instrument on the SST algorithm implementation.

3.2.1.8 Surface Temperature Maps – This paragraph states that low surface temperatures can be misidentified as clouds in some cloud detection tests when a lack of daytime solar radiance measurements exist. It is also true that this situation can be reversed because some cloud detection tests can misidentify relatively low warm clouds as clear ocean when a lack of daytime solar radiance measurements exist. This paragraph fails to address this situation. Such a situation is detrimental to SST retrieval accuracy, resulting in cloud contaminated pixels used to retrieve SSTs.

This paragraph also suggests using a VIIRS SST surface temperature map within the Cloud Mask. Such an approach is problematic in that the Cloud Mask – SST Retrieval relationship becomes incestuous, allowing Cloud Mask errors to propagate into the SST Retrieval process and SST Retrieval errors to propagate back into the Cloud Mask and so on and so forth. The SST surface temperature map used within the Cloud Mask must be independent of the Cloud Mask (i.e. not obtained from SSTs generated using the Cloud Mask).

3.2.2 Pixel Level Cloud Detection Tests…. - This section states that in the future, contrast tests will be developed using 2x2 image pixels. Such contrast tests may not work well for VIIRS channels. The VIIRS multiple detector per channel sensor design will generate striping from line to line and cause significant problems for contrast tests.

Table 6 – What solar zenith angle delineates the day/night decision for SST production?

Table 6 - For BT3.7-BT12 Night Ocean, does the threshold have to be greater than 0.6 or less than 0.6 to fail?

Table 6 - No visible reflectance channel is used for nighttime ocean cloud detection during twilight conditions. Solar illumination can affect the 3.7um channel temperature in twilight if the quantity of illumination is high enough. Failure to check for this quantity is detrimental to SST retrieval accuracy because the nighttime SST equation does not correct for solar illumination in the 3.7um channel.

Table 6 - No spatial uniformity tests are proposed for day ocean or night ocean cloud detection. Subpixel clouds may not be detected properly. Nor will cloud edges be detected properly.

Table 6 - No 11um minus 12um channel difference limit exists within the proposed Cloud Mask tests. When this channel difference exceeds about 4C, the water vapor content of the intervening atmosphere is large enough to preclude the retrieval of accurate SST retrievals. Under such conditions, it is questionable whether the 11 and 12 um channels are actually observing a low atmosphere temperature rather than the ocean surface. If this situation is not accounted for in the Cloud Mask, then the SST retrieval process must account for it. Presently, neither ATBD accounts for this situation.

3.3.2.3 BT11-BT3.7 Test – My operational experience has shown that this test does not detect all stratus in nighttime imagery over the ocean. Low, relatively warm uniform stratus and scud clouds are not always detected by this test, specifically when both channels register almost identical brightness temperatures. Failure to detect these clouds poses significant problems for SST retrievals because erroneous SST retrievals will then be made from cloud contaminated pixels. Use of a 13.3um channel significantly helps in the detection of these clouds.

3.3.2.4 BT8.6-BT11 and BT11-BT12 – The supporting publications listed for this test describe it to be most affective for detecting cold cirrus clouds. Figure 12 of the Strabala et al reference shows that this test has difficulty differentiating between water clouds and clear ocean. Therefore, one can conclude that warm uniform, low stratus clouds will not always be detected by this test. Such clouds pose a significant detriment to SST retrieval accuracy. Use of a 13.3um channel significantly helps in the detection of these clouds.

3.3.2.6 R.86 Test – Use of a single threshold value of 7% is not adequate for all daytime sun-satellite angle situations over the ocean. Specifically, dimly lit clouds from early evening or early morning will not be detected using a 7% reflectance threshold. Neither will subpixels clouds and cloud edges be detected. Use of a dynamic threshold that changes by sun-satellite geometry is a much more effective test. Failure to account for reflectance changes based on sun-satellite angle could result in cloud contaminated pixels being identified as clear ocean.

3.3.3.4 Imagery Resolution Contrast Tests – These tests are very powerful. However, they will be virtually ineffective due to the striping that will exist in the VIIRS data. This fact is unfortunate because subpixel clouds and cloud edges may not be adequately detected without use of these tests. Such clouds pose a significant detriment to SST retrieval accuracy.

From Peter Minnet, NASA:

Sea Surface Temperature., SBRS Document # Y2386, v3, May 2000.

This document covers a lot of material relevant to the derivation of sea-surface temperature (SST) from VIIRS infrared measurements. In general it gives the reader a sense of confidence that the people involved have a good idea of the types of issues involved. However, in many places they have not done justice to their efforts as the amount of detail needed for the reader to accept their conclusions is lacking.

General comments:

1. **As I understand it, the purpose of the document is to provide a reader, who is not necessarily very familiar with the instrument or the mission, the background to the formulation of the algorithm, the reason why various recommendations or decisions were made, and what are the expected accuracies of the derived product (SST) under realistic measurement conditions. The document goes a long way to achieve this, but the information content of various sections is quite uneven and, especially where details are too scant, needs to be much improved. For example, the section on aerosol effects (3.4.4) needs expansion if it is to convey the appropriate message, while that on post-launch calibration and validation (3.6.2) could be made much more succinct without loss of content. Also the authors need to recognize that the reader may not be aware of all aspects that are taken for granted by the writer. For example, in Fig 42, p60 what are characteristics of the six atmospheres used, and in Fig 44, p62, what are the 'noise models'?**
2. **Because of the diverse backgrounds of the readership the Glossary must be complete. What is the reader to understand by "The data were re-sampled to HCS for all GSDs after MTF models were performed." (p 62). None of these acronyms is defined.**
3. **The figures could have better text, in a clearer, larger font. I had to take a magnifying glass to read the axes and labels of several figures, eg. Fig 5.**
4. **The captions to the figures could be enlarged, quite significantly in many cases, to provide the necessary clues to understand the content of the figures and assess the message being put across, or the basis of conclusions drawn in the text. In many cases (eg Fig5) the captions are the same, or little more than, the figure titles. Perhaps the authors of this section were hoping to spare me reaching for the magnifying glass**

by repeating an illegible title as a bold caption, but this is not the purpose of the caption.

5. **The terms ‘precision, accuracy and uncertainty’ should be clearly defined, as it seems they are being used here with special meaning that is beyond their conventional usage.**
6. **I do not like the term ‘calibration’ applied to comparing satellite-derived SST with in situ (bulk or radiometric) measurements. Calibration is what happens on the spacecraft to produce calibrated radiances in the infrared channels, using the space view and the black body target(s). What happens thereafter is validation of algorithms, or optimizing coefficients or some such activity, but it is not ‘calibration.’**
7. **In several places the current accuracy of AVHRR is given as 0.5-0.7K. A recent publication (Kearns, E.J., J.A. Hanafin, R.H. Evans, P.J. Minnett and O.B. Brown, 2000. An independent assessment of Pathfinder AVHRR sea surface temperature accuracy using the Marine-Atmosphere Emitted Radiance Interferometer (M-AERI). Bull. Am. Met. Soc. 81, 1525-1536), which post-dates this ATBD, shows that when validated against radiometric skin temperatures, this is reduced to ~0.3K. This indicates that about half of the uncertainty previously attributed to the satellite SST is caused by thermal structure between the surface and the depth of the bulk sensor. Future versions of the ATBD should include this finding.**
8. **I find the absence of any reference to the AVHRR SST Pathfinder atmospheric correction algorithm and product surprising. Several publications have shown its worth and it is used in a large number of scientific studies. It provides the ‘benchmark’ SST product of the AVHRR, which VIIRS is intended to replace. It is the basis of the MODIS SST algorithm. Why is it missing here?**
9. **Throughout the document when reference is made to particular algorithm I would recommend that the equation number, as on pp19 and 20, also be given. This would avoid any confusion. The term ‘split-window algorithm’ is a generic term and could be used to describe many in the list, but is presumably used later in this document to refer to a specific algorithm (e.g. Fig 44).**
10. **More care and attention needs to be paid to explaining which input data sets have produced which results and how. For example, why are Figs 15-17 different from Figs 19-21? Do these figures reveal anything more than inadequacies in the input data sets? What are we meant to conclude from the similarities and differences of the two? Which, if any, better approximates the true conditions, and if one is better at this than the other, why include the inferior one?**

11. **It would be worthwhile to include a discussion of the causes of the differences between skin and bulk SSTs. This is an important aspect (as shown in 3.6.2), but the causes, and the magnitude of the effects, and the controlling parameters, are not discussed adequately.**

12. To assess the validity of the noise models we need to know what they are. Do any of them include effects like 'detector striping' or are they based solely on NEDT, as Tables 4 and 5 would suggest?

13. **In the discussion of the pre-launch validation of the atmospheric correction algorithm (section 3.6.1) it is stated that use will be made of AVHRR and ATSR data. Why not MODIS data? MODIS, unlike AVHRR and ATSR, includes measurements in the same channels as those proposed for the VIIRS SST algorithms!**

14. **From my experience I would say the numbers of cases being treated in the simulations is too small. There is a great risk of mistaking results that are dominated by sampling limitations as a generalized geophysical effect. Unless all of parameter space is occupied in a realistic fashion, the results are susceptible to misinterpretation.**

<u>**Specific Comments:**</u>

15. **p3. The Reynold's type blended SST fields are 'a' major source, not 'the' major source.**

16. p 4. It is true that MODIS will be a follow up the AVHRR SST algorithm, but it is a skin temperature product.

17. **p7. Why was an 11x11 pixel array chosen?**

18. <u>p11, Eq 1. There is a term missing in this equation that describes the downward-emitted atmospheric spectral radiance, reflected at the sea surface and transmitted up to the satellite radiometer. This term should also appear in eq 2. While it is small it is it not negligible. It may not change any of the conclusions presented here, but its omission is likely to influence the numerical values of the coefficients derived for the algorithms.</u>

19. <u>p14 , Fig 5d. It is usual to define temperature deficit ad Tb-Ts, not as shown here. The general situation is that the temperature measured in space is colder than that of the surface – as a result of the surface emissivity being <1, and the atmosphere being colder than the surface. So why are there values of Tb>Ts? Except in very rare occasions involving strong temperature inversions in moist atmospheres, Tb < Ts in all channels for all values of column water vapor distribution. Unless there is an error in this figure, this indicates a serious problem with the data that have gone into the analysis here and elsewhere.</u>

20. **p15, Eq (10) I would suggest a change in font in going to matrix notation (bold?). Otherwise this looks like a single channel expression with zero offset.**

21. **p 15. I think in general the term 'far-IR' is used for wavelengths longer than meant here, i.e. 20 micron and longer. If this is meant to mean 10-12 micron it should be so defined.**

22. p 15. What is the source of the data used in Figures 6 –8. These seem to have very few data points from which to draw any conclusions.

23. p18. Fig 9. What are the different noise models and which, if any, describes the likely instrument behavior?

24. p19. Why is the AVHRR Pathfinder formulation missing? I am uncomfortable with the tendency here to add complexity - squared terms and more channels. Squared terms explode the contributions of noise in the channel measurements, and the added channels introduce noise as well as information to the retrieval. If the 4.05 micron transmissivity is so good, why not have very simple algorithms based primarily on this channel?

25. **pp19-20. I would like to see the planned operational algorithms, and back-ups, highlighted in some way to separate them from the rest.**

26. p20. The term 'solar glint event' implies something rare or sporadic (a volcanic aerosol event, a solar flare event, ….) not something that happens every orbit.

27. **p21. Why was the threshold of 282K chosen?**

28. **p23. The second paragraph should be backed up by references.**

29. **p23. What is the expected range of alphas in Eq (23)?**

30. **p24. The end of section 3.3.2.3 comes abruptly. Any conclusions?**

31. **p24. Is the size of the data set (299) large enough to draw conclusions? Does it provide adequate sampling of atmospheric variability?**

32. p25. Figs 12 and 13. It is not clear what we are to understand form these. What is meant by 'valid aggregation' ?

33. **p26. Fig 14. This does not convey much information. The top panel should be a histogram to show how the data are distributed in terms of SST. The data in the lower panel should be sorted in increasing SST, which might reveal a trend or absence of one. Axes should be labeled.**

34. **p 27.Why include the solar zenith and azimuth angles? How does solar radiation enter into the simulations? More details please.**

35. **p35. The discussion of figure 22 leaves me totally confused. What is the message? What are the details of this particular study? Which algorithms are involved?**

36. **p41. Fig 26. Which algorithm is being used here? Table 4 listing the NEDTs for each model should appear before the figure, which uses these terms. Why not give the NEDTs explicitly in the figure legend**

instead of the Model Number? Or does the Model Number include more information than simply the NEDTs, in which case some explanation is required.

37. **p42 Fig 27. Same comments at 36.**
38. **p 43. Fig 28. How is the local minimum at SST ~275K explained?**
39. **p 44. By SWIR do they mean MWIR, or do they really mean ir channels at ~1-2 micron wavelength?**
40. **p 44. More details on what is meant by 'solar radiation correction'? Is it atmospheric scattering, or sun glitter? If sun glitter, how was the wind speed dependence handled?**
41. **p45. Fig 29. Why a local minimum at 275K, and a local maximum at 295K? What does this tell us about the algorithm(s)?**
42. **p46, Fig 30. Why maximum at 295K?**
43. **p47, Fig 31. Why maximum at 290K?**
44. p51, It would be useful to include a discussion of possible error sources, and how correlated, uncorrelated and anti-correlated errors can arise.
45. p53. Tables 6 and 7. Why go to 260K, 310K and 320K? These are outside the environmental range.
46. p53. Is the RVS analysis appropriate to the VIIRS design?
47. pp56-59. I would appreciate a discussion of what is shown here. Why local minima and maxima?
48. **p60. The first sentence, beginning Figure 42 shows, needs explanation of the terms used. It is written as though the reader already knows what are the SBRS 192 calibration perturbation models, the five typical SSTs and the six different atmospheric conditions are. More details please.**
49. **p60. The sentence beginning "It is shown.." is poorly worded. Usually a greater accuracy is a good thing, whereas here I understand it to mean specifications are not met.**
50. **p61. 3.4.3 This section reads as though it is an internal SBRS memo addressed to people who know without being told what are the various noise and MTF models. More details and explanations are needed. It serves little purpose to tell us that the "MTF model is SBRS Model 3" on subsequent pages. How are we supposed to understand what is going on here. If we are not intended to understand, why include this section?**
51. **p62. Fig 44. Are the noise models here the same as Table 4? In which case what are noise model 4 and the un-numbered (brown) model?**
52. p 70. 'duel' should be 'dual'

53. p70. 'may et al' should be 'May et al'

54. p72 Fig 53. Are the lines correctly labeled? In (a) is looks as though the 'corrected' and 'uncorrected' lines are coincident, and in (b), the 'corrected' is very much worse than the 'uncorrected.'

55. p72. 'do not very' should be 'do not vary'

56. p72. I find it hard to believe that the height of the aerosol layer does not influence the infrared measurements. To me, this indicates that the model does not represent reality. How, for example, are the aerosol phase functions treated?

57. p74. How do different cloud types come into the simulations of different aerosol types?

58. p75. What is really being shown in these panels and what are supposed to learn? The caption, simply repeating the titles, is of no help and the discussion in the text is inadequate.

59. p 77. Fig 58. Why do the lines representing different channels behave as shown? Why are some channels warmer than the SST and others colder? What determined the choice of SST=271K? This is below the freezing point of sea-water.

60. p 79. The argument about tropical clouds being more easily detected by the cloud mask algorithm is spurious. If the cloud tops are very much colder than the SST, then a much smaller fraction of cloud cover in a pixel will introduce an appreciable radiance error; more so than if the cloud temperature were closer to the SST. If visible channel data are being used (ie reflected sunlight during the day) to detect clouds, the situation is exactly the reverse of the argument given here, as the reflectance of a small fraction of high cloud in a pixel might be small enough to escape detection, and still contaminate the infrared measurements. The same level of infrared contamination by a low cloud would require a larger amount of the pixel to contain cloud and therefore be more readily detected in the visible.

61. p 80. Figure 60. What are the wavelengths of the three VIIRS bands being shown here?

62. p 82. What is the 'toughest situation' and why?

63. p 82. Figure 62. The letters for each panel are missing, and the caption does not agree with the titles of the individual panels.

64. p 83. Section 3.5.5. Will the pixels identified by the cloud mask be flagged as well as skipped?

65. p 85. In the revision, reference should be made to the Kearns et al paper; otherwise the statement about there being 'no alternative data [to

buoy data] available for calibration of skin SST' is clearly false. Also see comment 6 above about the use of 'calibration' here.

66. **p 86. I disagree with the way the author defines 'calibration' and 'validation' – see comment 6 above.**

67. **p 87. Again, I dislike the use of the word 'calibration' here.**

68. **p 87. Is it true that VIIRS will represent the latest in technology? I hope not, as the latest is usually plagued with unanticipated problems. What we need is something that is reliable, not necessarily the latest.**

69. **p89. Is 1700km half of the orbit or half of the swath?**

70. p90. Fig 63. These values of the skin-bulk temperature difference are unrealistically large. The measurements I have seen are about five to ten time smaller than these.

From Paul Menzel, NOAA

Comments on Cloud Mask ATBD

Operational cloud detection is critical to the accuracy of all VIIRS derived EDRs. The Cloud Mask ATBD does not present algorithms that will adequately detect all clouds; in particular (a) night time polar clouds will be almost impossible to identify, (b) low level, relatively warm stratiform clouds over the ocean at night will likely be misinterpreted as clear ocean pixels, and (c) night time very thin high cloud will be missed.

The role of spatial uniformity tests is not described very clearly. When and how will be these be used.

MODIS data should be used to simulate VIIRS effectiveness and compared to MODIS effectiveness in detecting clouds.

Table 6 – An 11um minus 12um BT difference should be used. This has been quite effective in MODIS for detecting high cloud (difference is small when cloud is high, larger when cloud is low or clear sky).

The cloud mask is severely hampered because

1. No channels are sensitive to CO_2
2. No channels are sensitive to UTH
3. No channel pairs can detect low level T inversion, since all channels view surface

From Richard Legeckis, NOAA

Comments on Ocean Current ATBD (# Y2403 Version 3 May 2000)

The color figures of ocean temperature and color patterns with overlays of surface current vectors illustrate that a VIIRS ocean current product could be generated.

It is suggested that a study is initiated to blend AVHRR and MODIS ocean current vectors with hourly GOES image sequences since the GOES provides superior continuity of ocean pattern recognition. This would be a way of developing a blended day-1 product between the VIIRS and GOES for coastal waters of North and South America.

However, my overall conclusion is that ocean currents will be a research application limited to specific locations and time intervals. This is due to the physics of the problem. The VIIRS is not designed to measure ocean currents. Instead, the motion of surface patterns of ocean temperature and color will be used to infer surface currents. This will not allow validation of the currents since none of the available independent measurements of ocean current can be related directly to the motion of ocean patterns observed by VIIRS.

The ocean currents from VIIRS will not work when surface temperature is isothermal. Therefore, currents such as the Gulf Stream and Loop Current will disappear from view seasonally (summer and fall for coastal USA south of latitude 35N). Furthermore, even when the Gulf Stream thermal boundaries are apparent, the strongest flow occurs at the core of the current and the displacement of the thermal boundaries is not indicative of the water particle motion in the core.

The VIIRS will provide some estimates of the direction of current flow and a relative sense of the rate at which patterns are displaced. This ocean current product will be most useful when it can complement concurrent observations from other satellites, such as TOPEX, MODIS, and GOES as well as direct observations from surface drifters (ARGOS), moored current meters and coastal radar (CODAR) current estimates

Specific comments Ocean Current ATBD:

3.0 3rd Par. An assumption is made that the currents estimated from changing temperature and color patterns should be similar and that these vectors could be blended. Color and temperature products should be kept separately until blending methods can be verified.

3.3.1 The semi-automated procedures and subjective nature of selecting the retrieval parameters will produce non-consistent products.

3.3.1 page-18 The calibrated brightness (BT) 11-micron channel may be best suited for ocean current measurements since scan line banding may be smaller than for the SST product. Effects of scan line banding are not addressed for ocean currents.

3.3.4 page-20 It appears that there is no way to test the accuracy of the ocean current product since each testing method (altimeters, drifters, XBT, coastal radar) provides only part of the current estimate while the VIIRS provides another part of the motion.

Fig 11 - 17 Examples of SST and color images appear to show some utility of VIIRS velocity vectors but it is difficult to quantify the agreement. In fact, the strongest flow is expected at the East Australia Current (32 to 35 South) but instead the satellite vectors appear very weak at this location.

However, last sentence on page 24 refers to Fig. 12 as "especially represented near the southern tip of Tasmania" but Tasmania is not on this map. Perhaps that should say northern tip of Tasmania (north of 41 South).

Dorothy K. Hall, NASA

Algorithm (EDR): **Snow Cover/Depth Version 3**

Approach:
The contractor is planning to use spectral-mixture modeling to calculate fractional snow cover globally with an accuracy of 10% at nadir. They plan to build an endmember library from in-situ observations available from numerous field observations of snow reflectance, and from reflectances from MODIS.

The contractor's method to determine snow-water equivalent (SWE) is not specified in detail.

Comments:
I have attached the reviews that I wrote for Version 2 of this ATBD. Most of the problems that I mentioned in the previous review have been addressed. However, there are still no details how they will use the passive-MW and VIIRS data together to map snow depth. Without the passive-MW data, it will not be possible to map snow depth. Even with the use of passive-MW data, it is extremely difficult to map snow depth in forested areas; the accuracies will be very low.

The contractor needs to expend more energy developing the passive-MW approach to mapping snow depth. There is an extensive body of literature on this subject, beginning in the mid 1970s. Even recent papers on this subject point to major impediments to the use of passive-MW data for accurate snow-depth determination.

Algorithm (EDR): **Sea ice age/edge motion Version 3**

Approach:
The contractor plans to use an approach that combines spectral-mixture modeling and an energy-balance model to determine sea ice age and edge motion.

Comments:
Attached is my review of Version 2 of this algorithm. The use of reflectance data to determine ice age is not reliable because snow cover often overlies sea ice. Thus the snow-covered first-year ice looks just like the snow-covered multi-year

ice. The use of the energy-balance model may be useful, but ice age cannot be determined with a high enough degree of accuracy using visible and near-IR sensors alone. Microwave sensors are more amenable to ice-age determination, but the resolution of passive-MW data is very poor.

Table 7 on pgs. 16 and 17 shows that the ice age can be determined based on ice reflectance. While this is true to a very limited degree, it is extremely problematic to implement a reflectance-based approach to ice age determination for most ice types since ice tends to be snow covered most of the time.

Algorithm (EDR): **Fresh Water Ice Version 3**

Approach:
The contractor plans to use spectral-mixture modeling, similar to that which is planned for determining snow cover, to map fractional lake ice cover on 19 large, inland lakes globally. In addition, they also plan to use VIIRS thermal bands to discriminate ice from water. They will use the surface temperature to map lake ice during darkness, too.

Strengths:
I have attached my review of Version 2 of this ATBD. The approach outlined herein and in Version 2 appears to be reasonable.

Weaknesses:
They should expand their analysis to more than the 19 lakes that they have specified in the ATBD.

Conclusion:
The contractor's approach to determining fractional lake ice cover remains sound.

Algorithm (EDR): **Ice Surface Temperature**

Approach:
The contractor plans to use a split-window technique as has been discussed by Key et al. (1994) to measure IST. They plan to use two IR bands: 10.8 and 12.0 μm. This method has been implemented by the MODIS team as well, for the IST algorithm.

Strengths:

This is a well-proven, low-risk method of determining IST. The required accuracy of 1.0 K should be obtainable.

Weaknesses:

In section 3.6.1, pre-launch validation, there is no mention of using MODIS for validation. This should be the key sensor to validate the NPOESS algorithm in the pre- and post-launch time frame.

Conclusion:

This is a proven and sound approach to measuring IST using VIIRS data.

In order to improve the accuracy of the IST measurements with NPOESS, improved atmospheric correction must be developed assuming the VIIRS sensor performance is as expected. Thus most of the pre-launch effort should be put into determination of improved atmospheric correction over the Arctic, since the split-window technique for calculation of IST is quite well established.